SOUTHERN ARIZONA–SOUTHWESTERN NEW MEXICO PROVINCE (025)

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INTRODUCTION

This geographically extensive, but unproductive province, covers about 60,900 sq mi from northwestern Arizona to southern Arizona to southwestern New Mexico, primarily in the Basin and Range Physiographic Province, but includes some of the northwest-trending Mogollon transition zone between the Colorado Plateau and the block-faulted terrain. Outcrops in the transition zone are mostly Early and Middle Proterozoic rocks and eroded remnants of Paleozoic and Mesozoic rocks covered by Cenozoic volcanics. Outcrops in the Basin and Range are eroded remnants of similar rocks being buried in their own debris. Except for the southwesternmost part of Arizona, which is geologically similar to the Salton Trough Province 016, the western half of province 025 has very little petroleum potential. Maximum thickness of Phanerozoic rocks is 25,000–30,000 ft in southwesternmost New Mexico.

Province 025 has an extremely complex geologic history that includes several major episodes of Phanerozoic tectonism. Deformation accompanied these province events: (1) Late Paleozoic interplate compression rejuvenated basement faults and formed basins and uplifts on the cratonic platform-shelf; (2) subduction to the southwest caused early- to-mid-Mesozoic magmatic arc emplacement and formation of the Mogollon highlands; (3) Early Cretaceous rifting (Bisbee Basin, that is, the northern extension of the Chihuahua trough-aulacogen); (4) Late Mesozoic to Eocene compression produced basement-cored uplifts and localized northeast-directed thrusting; and, (5) middle to late Cenozoic extension caused block and detachment faulting.

Precambrian, Paleozoic, Mesozoic, and Tertiary rocks are exposed in fault-block mountains surrounded by Neogene and Quaternary basin-fill alluvium. Metamorphic core complexes, plutons and other igneous intrusions, and world-class Laramide ore deposits occur within the area. For additional information see Butler (1989) and Jenny and Reynolds (1989a).

Evidence suggests that during the Precambrian a major (100-mi-wide), but enigmatic and controversial, west-northwest-trending shear zone, the Texas lineament (Muehlberger, 1980), may have existed between what is now the site of El Paso, Texas, and the present Pacific Ocean. It may be the longest zone of weakness, or wrench fault

(Sylvester, 1984), in the northern hemisphere. Movement in opposite senses probably occurred intermittently from Precambrian through Laramide times. Transpressional uplifts or anticlinal welts, tilt blocks, drag folds, local thrusts and normal faults, and pull-apart basins along slight changes in direction of the fault are probably present but obscured by later tectonism. Hydrocarbon traps may have been formed as a result of these structures. Examples of crustal sags associated with the shear zone might include the Late Paleozoic marine Pedregosa Basin and the area of southwestern Arizona where as much as 25,000 ft of the nonmarine Jurassic or Early Cretaceous McCoy Mountains Formation (Harding and Coney, 1985) was deposited. Other transform-like strike-slip movement has been documented on the Jurassic Mojave-Sonoran megashear (northern Mexico); it may be en echelon with the Texas lineament.

Paleozoic shelf sediments were deposited on a passive plate margin near the southwestern terminus of the transcontinental arch. Late Paleozoic petroleum source and reservoir strata were deposited in the sometimes-restricted Pedregosa Basin of southeastern Arizona and southwestern New Mexico. Figure 2 illustrates the stratigraphic column for the Pedregosa Basin. For a very brief tectonic and depositional history, see the discussion under Northern Arizona, Province 024.

In the eastern half of this province, the Triassic and Jurassic Periods were generally times of erosion and intrusive and extrusive igneous activity. Also, as much as 15,000 ft of Early and Late Cretaceous sediments accumulated in the Bisbee Basin; most were poorly sorted clastics, but Early Cretaceous basin-margin carbonate algal-rudist reefs did develop. Generalized Late Cretaceous depositional settings included alluvial fans adjacent to a coastal plain and a fluvial-marine deltaic complex.

Four speculative plays are considered in this province: two in the Pennsylvanian-Permian section of the Pedregosa Basin, one play in seven of the nonmarine Tertiary basins of southeastern Arizona, and one marine play of Neogene age in the Altar Basin (proto-Gulf of California) of southwesternmost Arizona. They are the Alamo–Hueco Basin Play (2501), Pedregosa Basin Play (2502), Seven Tertiary continental Basins Play (2503), and Altar-San Luis Play (2504). Exploration intensity has been light with approximately one borehole drilled per 325 sq mi.

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CONVENTIONAL PLAYS

2501. ALAMO HUECO BASIN PLAY (HYPOTHETICAL)

This hypothetical oil and nonassociated gas play is defined on Pennsylvanian and Early Permian source and reservoir rocks in the deeper part of the Pedregosa Basin of southwestern New Mexico. Evidence comes from the key stratigraphic section of the Big Hatchet Mountains (Wengerd, 1970; Thompson and Jacka, 1981) near the center of the play.

Reservoirs: Reservoirs might include fractured shales of the Horquilla Limestone. Sandy fluvial to deltaic clastic units (moderately sorted quartzarenite) of the 1,000-ft-thick Earp Formation have reservoir characteristics and may be sealed by Earp Formation micrites, reddish shales, and calcite-cemented siltstones, or by the superjacent Early Permian shales, impermeable carbonates, or gypsum beds. The Earp Formation is probably lithologically correlative with the gas-productive Abo Formation in southeastern New Mexico.

Source rocks: Potential source rocks are black, 2,500– 3,500–ft thick shales, mudstones, dark limestones, and reef carbonates of the Horquilla Limestone. The deep marine basinal mudstones probably reached thermal maturity during the Cretaceous Period and generated oil that migrated northward updip into coeval shallow-marine shelf dolomite facies (porous phylloid algal mounds). Vitrinite reflectance data from Paleozoic outcrops in southwestern New Mexico range from about R_o 0.6 to 1.8 percent. Thermal maturity increases southeasterly through the play into northern Mexico toward deeper pre-Laramide burial sites.

Traps: In addition to the stratigraphic traps within the Horquilla, as noted above, the various styles and times of complex deformation provide structural traps. An outline of tectonic events and associated structures is noted in the introductory section. Half-grabens, basement-cored uplifts, northeast-directed Laramide overthrusts, reverse and normal faults, right-lateral strike-slip wrench faults, and major northwest-trending folds are some of the potential trapping mechanisms in this play. The Paleozoic strata, which are 3,000 – 14,000 ft thick north to south, respectively, may have several thrust-repeated sections in the southern part. In the northern part, both the Paleozoic and Cretaceous sections may be involved in numerous thrust sheets. Drilling depths may be as much as 25,000 ft. Although gas is a stable hydrocarbon species in deep parts of this play, it may not have accumulated; that is, the gas-prone areas may have leaked due to the highly fractured and faulted reservoirs. Tectonic overprinting may not only have created traps, but also may have destroyed them, leaving few large accumulations possible.

Exploration status and resource potential: Few of the suspected deep traps have been drilled. Density of exploratory drilling is about one well per 40 sq mi; in the entire Pedregosa Basin this density decreases to one well per 1,340 sq mi for wells that have encountered either the Paleozoic or Precambrian rocks. Twelve boreholes in this play had significant oil and gas shows, and one, Humble Oil No. 1 State BA (TD 14,585 ft) had nearly commercial amounts of gas from the Permian Epitaph Dolomite.

Limiting factors to upgrading the petroleum potential include possible flushing of reservoirs by meteoric water and the rupturing of traps and seals by repeated post-migration Neogene Basin-and-Range faulting. Thermal destruction of hydrocarbons may have occurred in this highly-mineralized terrain close to plutons and volcanic cauldrons; however, the thermal effects of intrusions in some cases may actually mature the source rock and are not thought to severely alter the host rock more than a few tens of feet away from its contact with hot igneous rock.

2502. PEDREGOSA BASIN PLAY (HYPOTHETICAL)

This hypothetical, highly-speculative, oil and nonassociated gas play is in the Basin and Range Physiographic Province of southeastern Arizona. The play boundary is defined by thick upper Paleozoic strata (4,000–4,750 ft) that may contain some source rocks within the thermal zone of oil generation in the proximal part of the Pedregosa Basin. Outcrops in the horsts surrounding the play are over-mature with respect to oil.

Reservoirs: Potential reservoir rocks primarily include the Horquilla Limestone carbonates (see play 2501) and minor sandstones totaling on average of 1,000 ft thick for the formation, plus other intercalated upper Paleozoic marine shelf carbonates and tidal flat and deltaic siltstones and sandstones, for example, the Earp Formation totaling on average of 1,200 ft thick. The carbonates locally have vuggy porosity. Reservoirs may be sealed by upper Paleozoic units, such as the massive gypsum beds of the Epitaph Dolomite, or dense carbonates or fine-grained intercalated clastics below the Scherrer Formation, or the orthoquartzites of the Scherrer. Diagenetic porosity pinchouts between the various carbonate facies of the Colina and Epitaph may also prevent migration.

Source rocks: Potential source rocks of fair to average quality could include the dark carbonates of the Mississippian Escabrosa Limestone and Paradise Formation, the

Pennsylvanian carbonates and thin shales of the Black Prince Limestone and Horquilla Limestone, and the dark Permian shelf limestones, dolomites, and shales in the Earp Formation, Colina Limestone, Epitaph Dolomite, and Concha and Rainvalley Formations. The Pennsylvanian-Permian fossiliferous carbonates are consistently dark on fresh surfaces; some of these are biostromal and stomatolitic and produce thick oily residues upon dissolution in acid. Shows of oil and gas have been detected in all of the rock systems in the Pedregosa Basin; the ratio of shows to dry holes is greater than 1.0. Fetid odors are very common in outcrops of this play.

Timing and migration: Timing of generation and migration of hydrocarbons are unknown but may have been during early Cretaceous or Laramide time.

Traps: Various stratigraphic and structural traps are commonplace; the general types are listed in the province introduction. Unconformities as depicted in the stratigraphic section present an additional trap and seal potential. Targets are expected at 6,000- to 17,000-ft drilling depths due the extreme structural complexity of the area. This complexity may also be responsible for trap destruction.

Exploration status and resource potential: Drilling density in this play is about one petroleum-test borehole per 150 sq mi, and only one borehole is deeper than 10,000 ft.; there are only a few tests between 5,000 and 10,000 ft. The potential of this frontier area has been inadequately tested.

2503. SEVEN TERTIARY CONTINENTAL BASINS PLAY (HYPOTHETICAL)

This hypothetical, mostly nonassociated gas play is in the Basin and Range Physiographic Province of southeastern Arizona. The seven basins included are Tucson (Santa Cruz Valley), Sonoita-Cienega, San Simon (Safford Valley), Sulphur Springs (north), Sulphur Springs south (Elfrida), Teran (San Pedro north), and San Pedro (south).

Crustal relaxation and extension, which began in the Oligocene and was most pronounced during the mid-Tertiary, created a general horst and graben (listric block-faulted) terrane. Intermittent uplifting eroded the horsts, and the internally drained basins filled with thick sequences of continental alluvial-fluvial fanglomerates, various pyroclastic and flow volcanics, and lacustrine sediments. Rapidly rising horsts shed thousands of feet of very coarse (boulder conglomerates) to very fine clastics, (for example, mudstones) into the asymmetrical grabens and half-grabens.

The lacustrine deposits include evaporites of gypsum, anhydrite, and halite. These mostly Miocene and Pliocene salt masses have been estimated to be from 3,600 ft to more than 12,000 ft thick in the major Tertiary basins of the Arizona Basin and Range Physiographic Province. In the basins of south-central Arizona near Phoenix, they may be as much as 10,000 ft thick. Salt thickness is purely conjectural for southeastern Arizona; the tops of salt masses here may be from 500 to 3,000 ft below the surface. Depths to bedrock are about 4,000 ft to more than 12,000 ft (Oppenheimer and Sumner, 1980). Elevations of the Precambrian basement, that is, the graben floors, are about 6,000 – 10,000 ft below sea level.

The simple model of petroliferous lacustrine deposits, including stomatolitic carbonates, marly limestones, and various chemical precipitates, being rapidly covered by the clastic (reservoir) units and impermeable evaporites and clays (seals) as the lake shorelines shifted, serves as the basis for this play. Seven Tertiary basins, some having connections at the shallower depths, are included in this play; more basins in the Arizona Basin and Range Physiographic Province, may also have petroleum potential, but additional study will be necessary in order to include them.

Reservoirs, source rocks, and traps: Source and reservoir rocks are closely associated. Most of the Tertiary Pantano Group is clastic basin-fill; however, it is highly variable and may contain lacustrine deposits (organic-rich clays, evaporites, and carbonates) that could qualify as source rocks. Hypersalinity in the basinal lakes may have preserved organic matter that is possibly of types I, II, and III. These basins exhibit normal to anomalously high heat flow, plutonic and volcanic rocks, and thermal springs; although nonassociated gas is expected, including some biogenic gas, some oil may be present if maturation was augmented by igneous activity.

Environments of deposition in this play during the mid-Tertiary include pediment surfaces (for example, gravel) and alluvial fans near the play edges, and floodplain, fluvial, paludal, terrace, playa, subaerial dune, lake delta, and evaporating pan environments more distal to the source areas. These depositional facies, as well as the abundant layered volcanic units, change rapidly over short distances and could provide not only good reservoirs but also the porosity and permeability pinchouts necessary for trapping. Salt beds intertonguing with the terrestrial clastics may have also trapped migrating petroleum. Unconformable stratigraphic contacts are common and may only very locally prevent migration.

The role of diapirism in the salt masses is essentially unknown and currently indeterminable as to whether it may have caused structural traps to form in deformed beds. Targets are a few hundred feet deep to possibly more than 12,500 ft deep along basin axes. All potential petroleum reservoirs in the seven basins have a high probability of being flushed with meteoric water and fresh water is being heavily mined by relatively shallow water wells in some areas to support the needs of a rapidly increasing population and the agricultural and industrial economy.

Exploration status and resource potential: Several dozens of minor hydrocarbon shows are documented in the driller's logs of these basins; most are reported in water wells. More than a dozen minor oil seeps have been reported. Drilling density in this play is about one borehole per 70 sq mi, but only one petroleum borehole per every 410 sq mi. Only four boreholes have been drilled deeper than 5,000 ft in this play. This play depends on exceptionally unique geologic conditions to make it work, and therefore it has only fair hydrocarbon potential.

2504. ALTAR–SAN LUIS BASIN PLAY (HYPOTHETICAL)

This hypothetical oil and nonassociated gas play is in the Basin and Range Physiographic Province of southwesternmost Arizona (Yuma Desert). The play is defined by very significant onshore and offshore petroleum shows and possible discoveries in Cenozoic sand-shale sequences just to the south in northwestern Sonora, Mexico.

Source rocks: Transgressive Cenozoic (mostly Miocene and Pliocene) marine to brackish-water estuarine sediments were deposited in the deep, narrow, euxinic proto-Gulf of California along the present-day axis of the Colorado River (Armentrout and others, 1979). The shales and carbonates, for example, the Pliocene Bouse Formation, may contain as much as 10 percent total organic carbon in places (Guzman, 1981). Highly variable thermal maturities and hydrocarbon types suggest that gas, gas condensate, and oil can all be expected to occur; there may be some biogenic gas in the shallower parts of the play. The Exxon #1 Yuma-Federal well was drilled in 1973 to a depth of 11,444 ft; vitrinite reflectance measurement at TD was R_o 1.1 percent. Known geothermal resource areas are present just a few miles west of this play in the Imperial Valley-Salton Sea area. This close proximity may expedite the maturation of the shallower source rocks nearest the California border.

Reservoirs: Reservoir rocks of the Bouse Formation (about 1,000–2,000 ft thick) are within an admixed package of bedded volcanics, carbonates, and turbidites, (conglomerates, sandstones, siltstones, shales); the several thousand feet of Miocene clastics is the secondary target. Miocene evaporites and Neogene fine-grained clastics may provide reservoir seals.

Traps: Guzman (1981) suggested that the Altar Basin is genetically related to the oil-rich Los Angeles Basin and other Miocene basins of southern California, but offset by right-lateral movement along the San Andreas transform fault. Drag folding and push-up structures along this strike-slip fault system may have created hydrocarbon traps (see introductory section regarding Texas lineament structures). Facies changes over short distances, and hence porosity-permeability pinchouts are to be expected in this trough, which received a rapid accumulation of sediments. Fault traps may be present. Lastly, mid-Tertiary tilting creating angular unconformities, and erosion creating interformational disconformities, may also enhance petroleum trapping and accumulation. Generation and migration of hydrocarbons is probably still occurring.

Exploration status:

Seismic refraction data in the northern Gulf of California indicate that unconsolidated Pliocene(?) and Pleistocene sediments may be 5,000 ft thick; semi-consolidated Miocene (?) and Paleogene sediments may be 6,500 ft thick. Gravity studies indicate that Neogene sediments may be 10,000–15,000 ft thick between the Salton Sea and the northern Gulf of California. Depth to Cretaceous bedrock is probably 11,000–13,000 ft in the play.

Miocene gas, possibly commercial, was discovered at a depth of about 13,500 ft as reported in 1981 (see Nations and others, 1983a, for references to the original information) in the northern Gulf of California area 14 mi offshore. Either another discovery may have been made in 1982, or else confirmation and development wells may have been drilled near the 1981 discovery. Accurate information is difficult to obtain, but existing information indicates that the 1981 (or 1982 wells) encountered deltaic sediments of the Colorado River and yielded a gas and condensate discovery in a Pliocene-Pleistocene section 13,000–19,700 ft thick, gas and oil flowed at almost 6 MMCFGPD and 30 BOPD. Other Pemex discoveries have been reported in 1983, 8 mi south of this play. In 1985 gas zones and salt beds were drilled in 16,400 ft of Neogene strata about 30 mi south of the southeast tip of this play in Sonora, Mexico; water production caused abandonment of the well. About two dozen petroleum boreholes, some having shows, have been drilled in the Yuma area of the United States; five of these are more than 5,000 ft deep.

UNCONVENTIONAL PLAYS

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

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